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SUBWATERSHED CLUSTERING BASED ON GEOMORPHIC AND HUMAN INDUCED LANDSCAPE MODIFICATIONS: THE COMMONWEALTH OF KENTUCKY

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Effective watershed assessment processes are needed that classify watersheds by geomorphic and human modified landscape scale characteristics. This platform presentation continues and expands upon the 2008–2012 KWRRI Symposium presentations. The research continues exploring the opportunities and constraints of the descriptive categorization approach that has been a central work focus for several years. For this presentation, the sample size has been increased to over 9000 subwatersheds spanning 13 river basins and encompassing the entire Commonwealth of Kentucky. Using a semi-automated and iterative process through ModelBuilder of ArcGIS and publically available data from the Kentucky Geography Network, over 100 indicators are derived by Hydrologic Unit Code (HUC) 14 subwatersheds to describe characteristics. Indicators derived include proportion and spatial configuration measures of human geomorphic characteristics, imperviousness, and agriculture/forest cover characteristics as well as changes in topography and several land cover types over a five-year period.

Drawing on over a million pieces of descriptive data allows for a plethora of analytical opportunities. For example, the subwatersheds can be visualized geographically with a color ramp by indicator independently or in combination. A quantitative matrix can be used to allow for subwatershed comparison, ranking, and/or prioritization. This enables the data to be used for a variety of purposes by hydrologists, environmental scientists, planners, policy makers, and interested stakeholders. This presentation will focus on the recent categorization effort. A Ward’s Minimum Variance Cluster Analysis approach based on 12 geomorphic and human influenced variables was utilized to identify 13 subwatershed types. These data and the statistical clustering approach are presented in a way to give a different subwatershed perspective for the Commonwealth. The research intent is for a better understanding of scenario development options as well as management opportunities and constraints.

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IMPERVIOUSNESS AND GREENNESS: EXTRACTING WATERSHED METRICS FROM BI-TEMPORAL, MULTISPECTRAL AERIAL IMAGERY AND LiDAR

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Imperviousness and the extent and type of vegetative cover are two watershed indicators of relevance in determining potential impact of human activities on water quality and quantity. The intricate geography of the Commonwealth, the patterns of land ownership and the dynamic nature of these two variables make it difficult for their monitoring to be carried out by frequent and sampling-intensive ground visits. Remotely sensed data, from either passive sensors (i.e. aerial digital mapping cameras), or active sensors (i.e. LiDAR), are becoming commonplace for Kentucky, and the data generated are becoming sophisticated enough to allow for the extraction of geospatial information with increasing ease. A mixed-use watershed in Northern Kentucky – Allen Fork, was used to explore the utility of several analytical approaches (Kentucky Division of Water, 2010). High accuracy LiDAR elevation and intensity data, and 4-band, 0.3048 m resolution digital aerial orthophotography were acquired in a near-synchronous fashion in the spring of 2012 from the Kentucky Aerial Photography and Elevation Program (KYAPED, 2012). Four-band, 1-m spatial resolution 2012 images were acquired in the summer of the same year as part of the National Agricultural Imagery Program (NAIP) (Kentucky Geoportal, 2012). The preprocessing workflow included the following main operations. QCoherent™ LP360™ v.2012.1.22 and Esri® ArcGIS® Desktop v.10.1 SP1 were used to process LiDAR point clouds and generate a digital elevation model, a normalized digital surface model, and first and ground return intensity images. The 2012 NAIP image was co-registered to the 2012 KYAPED dataset using the Autosync® module of ERDAS IMAGINE® v.2013. Three different techniques – two pixel-based, and one object-based, were explored with the purpose of extracting impervious surfaces and different vegetative land cover types (e.g. forested, non-forested) [Figures 1(a), 1(b) and 1(c)]. First, the LiDAR derivative data layers were stacked with the imagery bands, and run through Principal Components Analysis (PCA) and later unsupervised classification using the ISODATA algorithm. Secondly, a Normalized Difference Vegetation Index (NDVI) was calculated for both aerial digital images (Lillesand et al., 2008); class break values were manipulated in order to extract forested vegetation. Thirdly, the Objective® module of ERDAS IMAGINE® v.2013 was used to perform object-based image analysis and feature extraction on the NAIP, KYAPED images. The thematic mapping accuracy of the different methods was assessed by applying a Kappa analysis (Plourde and Congalton, 2003).

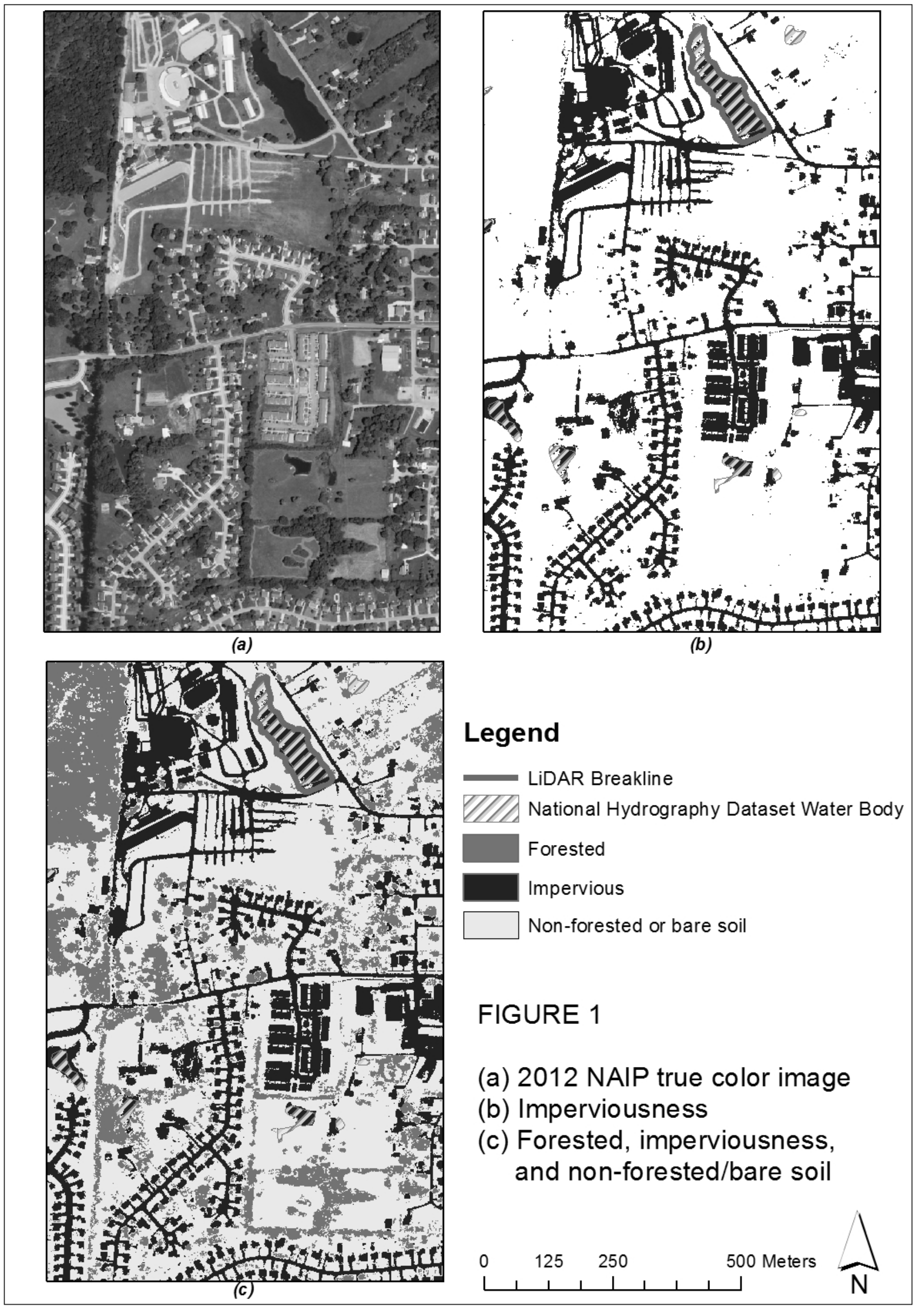

FIGURE 1

(a) 2012 NAIP true color image
(b) Imperviousness
(c) Forested, imperviousness, and non-forested/bare soil

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LANDSCAPE SCALE ASSESSMENT OF SOIL MOISTURE VARIABILITY USING AUXILIARY SENSING TECHNOLOGIES AND MULTIVARIATE GEOSTATISTICS

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Recent drought trends across the United States have heightened interests in finding efficient means to rapidly assess and map soil moisture. It is important to assess soil moisture to develop strategies to better manage its availability and use. At the landscape scale, soil moisture distribution derives from an integration of hydrologic, pedologic and geomorphic processes that cause soil moisture variability (SMV) to be time, space, and scale-dependent. Traditional methods to assess SMV at this scale are often costly, labor intensive, and invasive, which can lead to inadequate sampling density and spatial coverage. Fusing traditional sampling techniques with georeferenced proximal sensing provides an alternative approach. Georeferenced proximal sensing (e.g. such as geoelectric sensing and LiDAR) acquires rapid, real-time, reiterative, non-invasive, high resolution data over large spatial extents that is enriched with spatial, temporal and scale-dependent information. Because geoelectric and LiDAR measurements are sensitive to soil properties and terrain features that affect soil moisture variation, they are often employed as auxiliary measures to support less dense direct sampling. The onset of fusing direct and auxiliary measures requires finding techniques to effectively process this information.

Multicollocated factorial cokriging is one technique of multivariate geostatistics to fuse multiple data sources collected at different sampling scales to study the spatial characteristics of environmental properties. With multivariate geostatistics sparse observations of the primary soil attributes can be complemented by secondary attributes that are more densely sampled. Incorporating secondary information can lead to a more consistent description of the property under study. Factorial cokriging is a geostatistical method developed by Matheron (1982) and the underlying theory has been described in many papers (Castrignano` et al. 2000) and books (Wackernagel 2003). The approach consists of decomposing the set of original second-order random stationary variables into the sets of reciprocally orthogonal regionalized factors, one for each spatial scale used in fitting the nested linear model of coregionalisation (LMC) (i.e. a linear combination of basic variogram functions). Multicollocated factorial cokriging is a simplified version of the standard approach when the auxiliary variable is known at all nodes of the interpolation grid.

This study uses multicollocated factorial cokriging analysis to determine the spatial scale(s) in which soil properties and terrain attributes affect SMV. Variables for this study were established using high resolution geoelectric and LiDAR data as auxiliary measures to support direct soil sampling (n=127) over a 40 hectare Central Kentucky karst landscape. Shallow and deep apparent electrical resistivity (ERa) were measured using a Veris 3100 in tandem with soil moisture sampling on three separate dates with ascending soil moisture contents. Terrain features were produced from 2010 LiDAR returns collected at <1 m nominal pulse spacing. Exploratory statistics revealed 12 variables that best associate with soil moisture, including terrain features (slope and elevation), soil physical and chemical properties (calcium, organic matter, clay and sand) and geoelectric measurements (apparent electrical resistivity for each date). The LMC consisted of 3 basic components: nugget, cubic (short range scale) and exponential (long range scale). Applying principal component analysis to the coregionalization matrix at each spatial scale produced a set of regionalized factors summarizing the variation at that spatial scale. Preliminary findings indicate ERa mainly affects short range variation while soil properties and terrain features mainly affect long range variation. Thematic maps of the significant regionalized factors detail the scale-dependent spatial variability of soil and terrain properties affecting SMV. This study shows that SMV originates from multiple properties acting in a scale-dependent manner and uses multicollocated factorial cokriging to delineate measured soil and terrain properties affecting SMV into scale-dependent homogeneous zones. These maps could be used to direct a more rational, site-specific use of water and other natural resources.

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FIELD-SCALE BROMIDE LEACHING AS AFFECTED BY LAND USE AND RAINFALL CHARACTERISTICS

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Natural heterogeneity in soil properties limits the understanding of water and solute transport at the field scale. A new experimental design with scale-dependent treatment distribution was adopted to assess the impact of land use and rainfall characteristics on Br^- leaching under field conditions in this study. On a transect with two land use systems, i.e., cropland and grassland, rainfall intensity and the time delay between solute application and subsequent rainfall were arranged in a repetitive pattern at different scales. Soil samples in 10 cm increments down to 1 m depth were collected along the transect for Br^- analysis after rainfall simulation. Owing to the more continuous macropores supporting the development of preferential flow, soil Br^- was more evenly distributed with soil depth and reached greater depth in grassland. Increasing rainfall intensity tended to enforce the deep leaching of Br^-. Frequency-domain analysis revealed that the dominant factor that controlled Br^- leaching varied with depth. At 0-10 cm, rainfall intensity was most strongly correlated with Br^- concentration; while in the soil layer right below, application time delay was the main driving force for the spatial distribution of Br^-. With the increase of soil depth, the spatial behavior of Br^- was mainly caused by soil properties such as soil texture and topography, rather than rainfall characteristics. Nevertheless, rainfall intensity was found to be positively correlated with Br^- concentration in deep soil, indicating a great risk of deep leaching and groundwater contamination under heavy rainfall. Results of the present study suggest that this novel experimental design is useful in studying hydrological processes at large scales.

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